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WESTERN CANADIAN SURFACE MINING TECHNOLOGY

R.K. Singhal, D.B. Stewart, T.S. Golosinski, P. White

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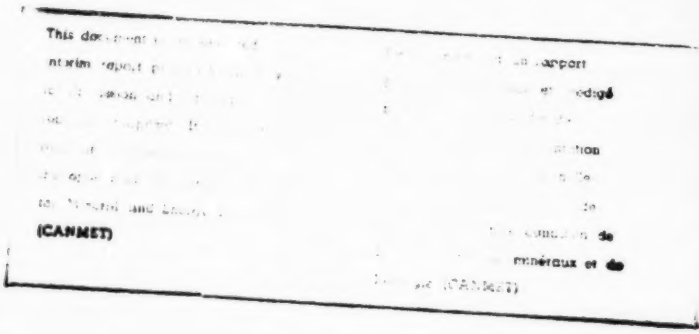

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by

R.K. Singhal*, D.B. Stewart**, T.S. Golosinski*** and P. White****

ABSTRACT

Western Canadian surface mining of solid and liquid fuels started in earnest in 1967 - coal in response to Japanese demands for metallurgical coal and oil sands to meet the ever increasing demand for liquid fuels.

This paper reviews the current status of mechanization in this industry and highlights the innovative practices adapted and developed by the coal and oil sands surface mine operators. It is a record of achievement.

Also discussed are the application of newer technology some of which is still on the drawing boards. Application of microprocessor technology to mine equipment and the issues of automation and remote control have also been reviewed.

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TECHNIQUES D'EXPLOITATION MINIÈRE EN SURFACE DANS L'OUEST CANADIEN

par

R.K. Singhal*, D.B. Stewart**, T.S. Golosinski*** et P. White****

RÉSUMÉ

L'exploitation minière en surface des combustibles solides et liquides a commencé sérieusement dans l'Ouest canadien en 1967 - l'exploitation du charbon afin de satisfaire à la demande du Japon d'obtenir du charbon métallurgique, et l'exploitation des sables pétrolifères pour répondre à la demande croissante de combustibles liquides.

Le présent rapport étudie l'état actuel de la mécanisation dans cette industrie minière et souligne les innovations adaptées et mises au point par les exploitants de mines à ciel ouvert de charbon et de sables pétrolifères. C'est un exemple de réussites remarquables.

On y discutera de plus de l'application des nouvelles techniques dont certaines sont encore à l'état d'ébauche. Enfin, l'application de la technologie du microprocesseur à l'équipement minier et les questions ayant trait à l'automatisation et à la télécommande sont aussi traités dans ce rapport.

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INTRODUCTION

A sizeable surface mining industry exists in Western Canada. There are the surface coal mines in Alberta, British Columbia and Saskatchewan producing the bulk of Canadian coal. The two oilsands plants in Fort McMurray producing synthetic crude oil are surface mining operations. Much of the metalliferous mining in British Columbia, is carried out by open-pit methods.

The western Canadian surface mines are highly mechanized, use world-class equipment and mining methods. It has taken this industry some twenty years to achieve this level of maturity and sophistication.

The western Canadian metalliferous and surface coal mines have many special features due to the geology and location of the mineral deposits. At the same time they also have many common features with many of the surface mining operations carried out in other parts of the world. The oilsands development is however unique to Canada - western Canada in particular. For this reason in this paper greater emphasis has been placed in discussing the surface mining technology of oilsands operations.

Canada, Venezuela, the United States, Africa, Europe and the U.S.S.R. all have major oil sands deposits. However, Canada is a forerunner in the development of oilsands mining and processing technology.

At present two commercial plants with an aggregate capacity of 32,000 m^3 (200,000 bbls) of syncrude per day are operating in Fort McMurray, Alberta. Each of these plants represents billions of dollars of investment in mining and processing facilities. At both plants, high capacity nearly continuous mining equipment is used for material handling. Typically, a plant that produces 19,900 m^3 (125,000 bbls) of synthetic crude oil per day would require the handling of some $54\text{-}58 \times 10^6$ m^3 of pit materials per year. This should give an indication of the enormous size of these operations. (Figure 1).

Fig. 1 - General view of Syncrude's oil sands plant.

Despite a low level of oil prices in 1986, the value of synthetic crude oil produced by surface mining methods, (all of it in Alberta), was approximately 1.26 billion dollars ($1.26 x 10⁹). For comparison the 1986 preliminary estimates place the entire Canadian metal production at 8.9 billion dollars ($8.9 x 10⁹). The significance of oilsands development to the western Canadian economy is obvious. (Table 1)

Table 1 - Mineral coal and synthetic crude oil production in Canada (1986P)

Metals	Unit Measure	1986 Quantity (thousands)	1986 $ Value (thousands)
Antimony	kg	3,900	23,910
Bismuth	kg	260	2,425
Cadmium	kg	1,421	5,434
Cobalt	kg	2,486	56,242
Columbium (Cb_2O_5)	kg	X	X
Copper	kg	768,244	1,567,988
Gold	g	104,655	1,715,392
Iron Ore	tonnes	36,096	1,254,758
Iron, remelt	tonnes	X	X
Lead	kg	303,503	204,427
Molybdenum	kg	12,914	113,942
Nickel	kg	180,599	1,075,467
Platinum group	g	8,793	X
Selenium	kg	334	5,742
Silver	kg	1,219	310,102
Tantalum (Ta_2O_5)	kg	39	2,124
Tellurium	kg	16	547
Tin	kg	X	X
Tungsten (WO_3)	kg	1,786	X
Uranium (U_3O_8)	kg	10,977	923,838
Zinc	kg	1,055,103	1,304,107
Sub Total I			$8,944,159
Coal	tonnes	57,800	$1,851,000
Synthetic crude oil	m^3	10,551	$1,264,000

(Table based on Mining Association of Canada data)

STATUS OF SURFACE MINING IN WESTERN CANADA

The volume of materials handled, the nature of the mined mineral and the processing techniques of producing a market oriented product in the case of coal and oilsands are very different. For this reason western Canadian surface mining technology is described in two parts, the first dealing with coal mining and the second with oilsands. Cross reference has been made as necessary to develop a better understanding of the subject as well as to identify the degree of similarity between the two industries.

Metal mining operations in western Canada are mostly copper producing. The equipment, mining methods and excavation and materials transportation technology is generally similar to that used in coal mining except for the differences in ore and overburden characteristics requiring heavier duty equipment in some cases.

SURFACE MINING OF COAL

Geology

Geology plays an important part in the selection of equipment and a mining method. The thickness and number of seams, their dip, thickness and nature of interburden, thickness and nature of overburden, quality of coal in seams, presence of folds, faults and other complexities, lateral extent of coal field and sub-surface water all influence the choice of equipment and mining methods. For this reason a brief overview is provided of the geology of the main coal fields in the three western Canadian provinces.

Figure 2 shows the distribution of Canadian coalfields whereas Figure 3 shows the coal deposits of Alberta and British Columbia. Several Canadian provinces have coal resources but Alberta is estimated to have the largest reserves of bituminous and sub-bituminous coal.

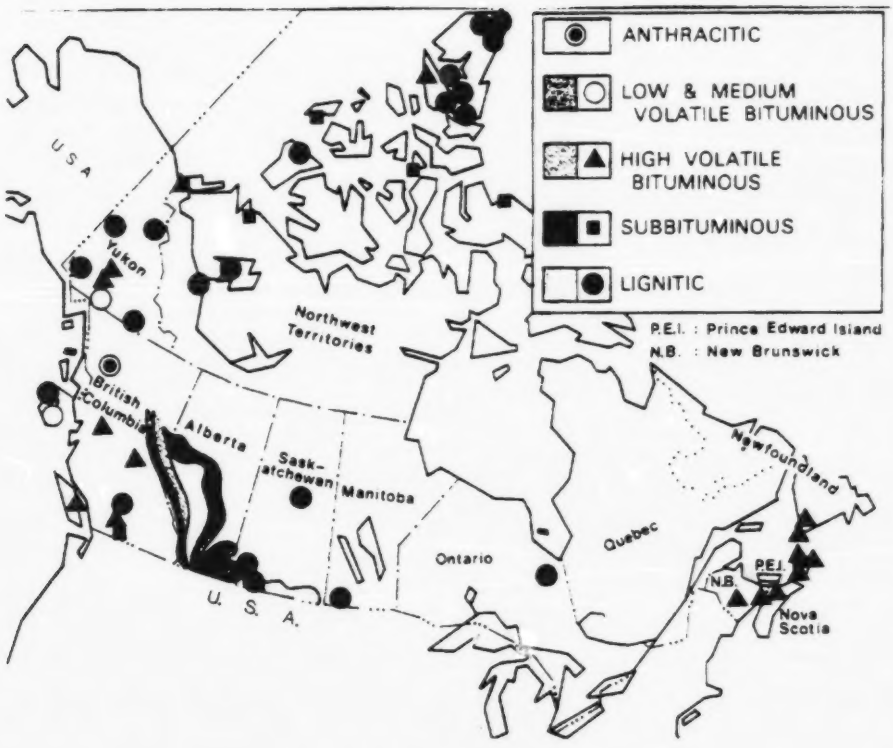


Fig. 2 - Coal in Canada.

The province of Alberta is divided into three regions each containing deposits of similar age and characteristics. These are the Mountain, Foothills and Plains regions. The Mountain Region extends along the eastern flank of the Rocky Mountains; it contains mostly medium and low volatile bituminous coal deposits mainly of Upper Jurassic and Lower Cretaceous age. The coals are commonly friable. The coal bearing strata are highly folded and faulted which has caused considerable tectonic thickening and thinning of coal seams in certain locations.

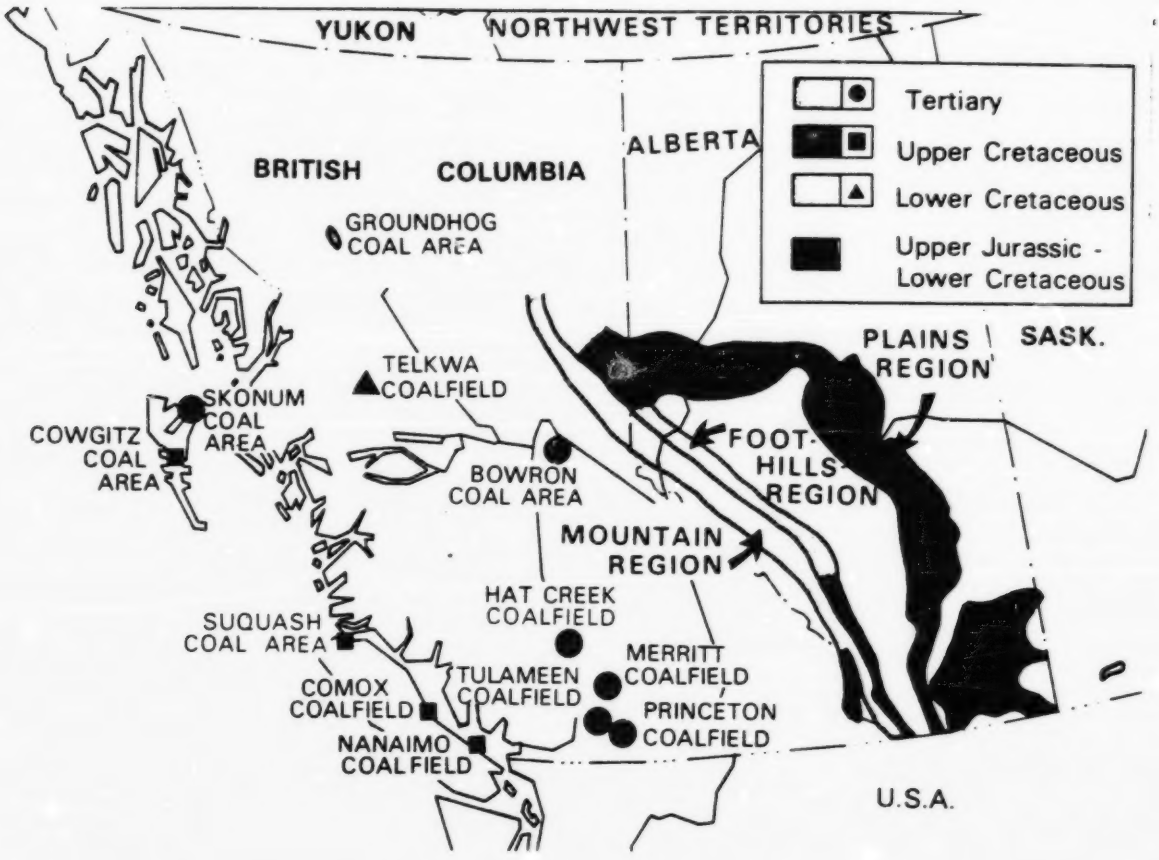


Fig. 3 - Coal deposits of Alberta and British Columbia

The Foothills Region adjoins the eastern edge of the Mountain Region and contains mainly highly volatile bituminous coals of Upper Cretaceous and Lower Tertiary ages. Like their counterparts in the Mountain Region these coalfields have been sheared, faulted and folded, and in certain locations show considerable thickening and thinning of coal seams.

The Plains Region coal is mostly sub-bituminous in rank mainly of Upper Cretaceous and Lower Tertiary age. Most of the seams of this region are flat-lying except those close to the surface that have been glacially disturbed.

As can be seen in Figure 3 coal deposits of the province of British Columbia are widely scattered.

The coal deposits of southeastern British Columbia (Crowsnest Coalfield) are Upper Jurassic in age and are part of the southern end of the Mountain Region as described for Alberta, with the notable difference that they contain considerably more seams that are of greater thickness than in adjoining areas of Alberta. The coal deposits of northeastern British Columbia are however Cretaceous in age and are the northern extension of the coals that occur in the Mountain Region of Alberta. Several small basins of Tertiary coal occur in the south-central part of the province including Tulameen, Princeton, Merritt and Hat Creek. Most of these basins contain coal seams which are intensely folded, faulted, and irregular in thickness.

In Saskatchewan seams of Paleocene lignitic coal of mineable thickness occur mainly in four coal basins: Estevan, Willowbunch, Wood Mountain and Cypress. Estevan coalfield is the most easterly and extends into the states of North Dakota, Montana and Wyoming. It is classified as lignite "A" and is Tertiary in age. Topography of the region is relatively flat. The only other active coalfield in Saskatcheawn is the Willowbunch.

MINING METHODS

In the provinces of British Columbia and Alberta, most surface coal mines are open pit terrace operations. The operations use truck shovel methods of extracting multiple coal seams from several multi-bench work faces. (Figure 4). While only one coal operator in the mountainous region uses a dragline, several draglines are being used in the foothills and plains regions of Alberta. Saskatchewan lignite is also mined with high capacity draglines.

Overburden is excavated mostly by cable shovels and front end loaders; although recently the hydraulic shovel has also gained considerable acceptance. Electric cable shovels with 11, 19 and 23 m^3 rock dippers form the major excavation unit.

Overburden is hauled to waste dumps either within or outside of the pit boundary by rock-body trucks. The most popular size is 154 tonnes (170st) but trucks of 90 tonnes, 110 tonnes and in the case of one truck even 315 tonnes are currently being used.

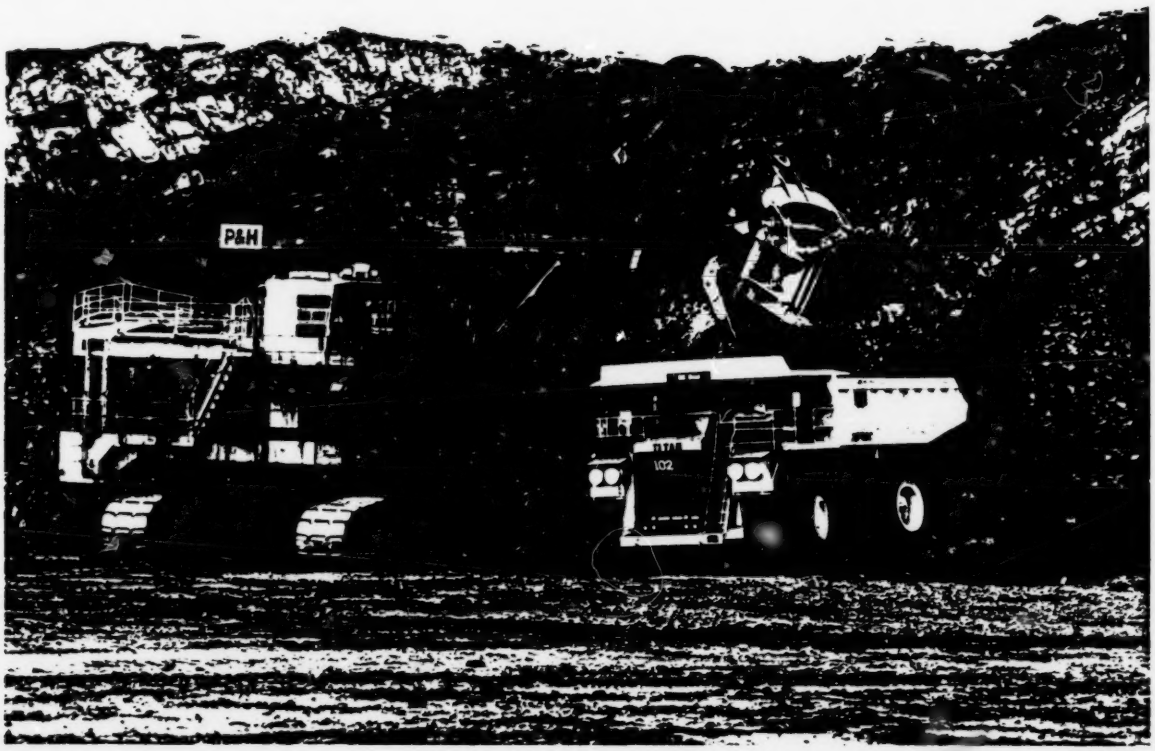


Fig. 4 - Truck shovel methods predominate in wetsern Canadian surface mines.

The top soil and unconsolidated material is removed by a variety of mobile equipment; hard consolidated overburden is drilled and blasted. The primary explosive used for blasting is ammonium nitrate - fuel oil (ANFO). In harder rock aluminized ANFO containing 3 to 7% of Al is generally used.

Western Canadian coals are friable and do not require drilling and blasting. Coal is usually loaded by front-end loaders and/or hydraulic shovels into coal body trucks. Front end loaders and hydraulic shovels of up to 19 m^3 bucket capacity are being used. In some cases in flat lying seams, cable shovels are used to load bottom dump trucks.

In terraced pits the bench heights are between 12-15 m overall with pit slopes 45 to 50° with some localized steeper slopes. In seams dipping greater than 30° benching of the footwall may be needed to create safety berms. In some cases dewatering may be necessary to release artesian pressure and stabilize the pitwalls. In other cases rock bolting of the footwall has been utilized.

Haulage road widths, determined by the size of the equipment in use, are 25 - 30 m wide and grade between 6 - 10%. Depending upon the topography at the mine site end tipping or area dumping of the overburden is carried out.

Lignite in Saskatchewan is exclusively mined by draglines. There are close to thirty large capacity draglines operating in western Canadian surface mines. (Figure 5)

Fig. 5 - Dragline operation in Saskatchewan lignite

SURFACE MINING OF OIL SANDS

In Canada the first commercial plant to extract bitumen from oil sands for processing to syncrude was installed in 1967 by Great Canadian Oil Sands Ltd. (now Suncor Inc.). The second commercial plant managed by Syncrude Canada Ltd., came on stream in 1978.

At the time of writing, due to significantly lower oil prices compared with those of the boom years (1980-81) the work on the development of new oilsands projects is at a slow pace. However, both existing oilsands mines are examining the prospects of an expansion increasing the combined syncrude capacity from the two mines by another 10-15%.

The bituminous sands that constitute the ore body at Suncor and Syncrude mine sites are contained within the Fort McMurray Formation (Figure 6). Bitumen concentrations average 11% to 12% by weight but range from less than 1% to 18%. Ore grading a minimum of 6% by weight is considered pay ore and is processed.

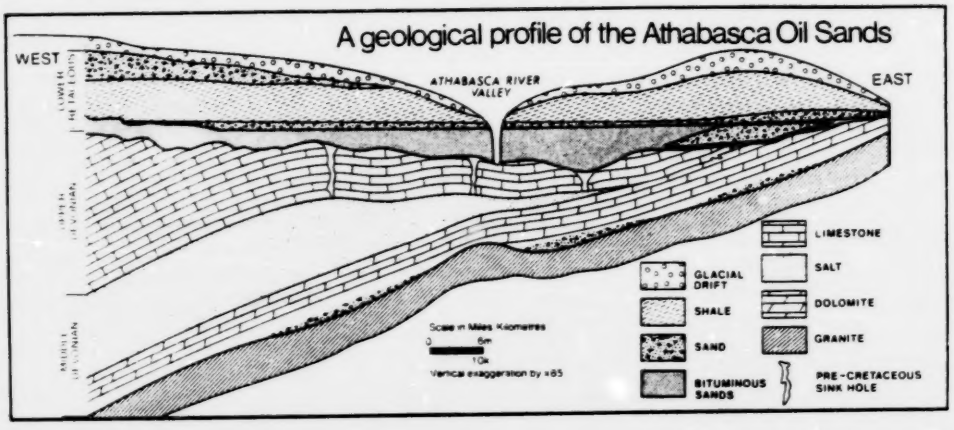


Fig. 6 - A geological profile of the Athabasca oil sands

Although both operating oilsands plants use the hot water process for extracting bitumen from the oilsands different types of primary equipment are used. The Syncrude mine uses draglines for mining the ore

whereas Suncor uses bucketwheel excavators. At both operations shovels, front-end loaders and other rubber and track mounted equipment is used for overburden excavation.

The Syncrude minesite (Mildred Lake) is located in the northern part of the Athabasca oilsands deposit. It is located 40km northeast of Fort McMurray. Figure (7) shows Syncrude's overall process of synthetic crude oil production from the oil sands.

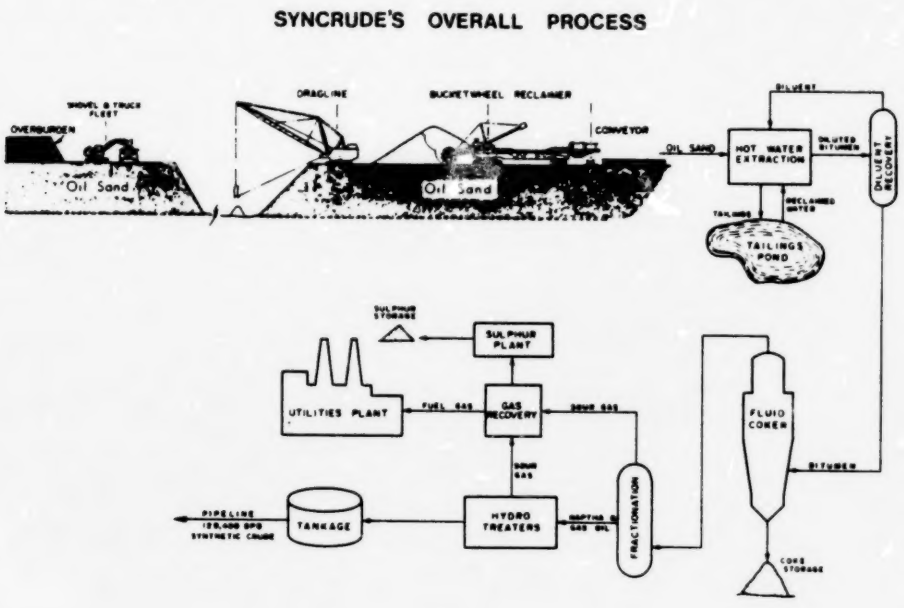


Fig. 7 - Flowsheet of overall process of producing synthetic crude from oil sands - Syncrude Canada Ltd.

At Syncrude overburden is excavated by conventional mining equipment. Hydraulic and electric shovels as well as front end loaders are used to load 154 tonne (170t) off highway trucks. The oilsand is excavated by four draglines, equipped with 60m³ buckets and 100m booms. These mine a single bench highwall, which varies from 40m to 60m. The highwall slope

angles vary from 45 to 50 degrees. The feed grade oil sand is windrowed on the dragline bench, adjacent to the draglines. Waste materials encountered in the dragline cuts is rejected into the mined out pit. (Figure 8). The windrowed oilsands is reclaimed by four bucketwheel reclaimers, (BWR) discharging onto face conveyors. The face conveyors discharge to collector conveyors, which in turn, discharge onto radial stackers. The stackers place the oil sand on a 240,000 tonne stockpile over the extraction plant draw points.

Fig. 8 - Mining of oil sands by draglines at Syncrude's oil sands plant

The Syncrude mine is the largest surface mining operation in the world in terms of the volume of materials handled. Its mining area extends 4.2km in the north-south direction. It is 7.5km wide and approximately 60m deep. It is divided into four 2,300 m long quadrants, each quadrant equipped with a dragline, a nominal 7,000 tonnes per hour bucketwheel reclaimer and a conveyor system. The tailings pond at Syncrude is 8km long and 4.8 km wide with perimeter dykes extending a total length of 20.9 km making it the

largest tailings pond in the world. At current production levels, the Syncrude pond receives between 260,000 and 315,000 tonnes per day of slurry.

The Suncor mine is the smaller of the two oilsands plants operating in Canada. Production of oil sand is in the range of 40 x 10^6 tonnes per year. This yields a synthetic crude oil output of approximately 60,000 bbls per day.

Like Syncrude, the overburden is excavated by conventional mining equipment. A fleet of front end loaders and hydraulic shovels are used to load off highway trucks. Until recently, 154 tonne (170t) electric trucks were used.

Unlike the Syncrude mine, Suncor uses bucketwheel excavators for mining oilsands. (Figure 9). At this mine, oil sands varies in thickness from 36m to 61m. It is mined in three benches each about 15m high. (Figure 10). Each bench is equipped with its own bucketwheel beltwagon and face conveyor. The bucketwheel has a theoretical excavating capacity of 3,600m^3/hr of loose material.

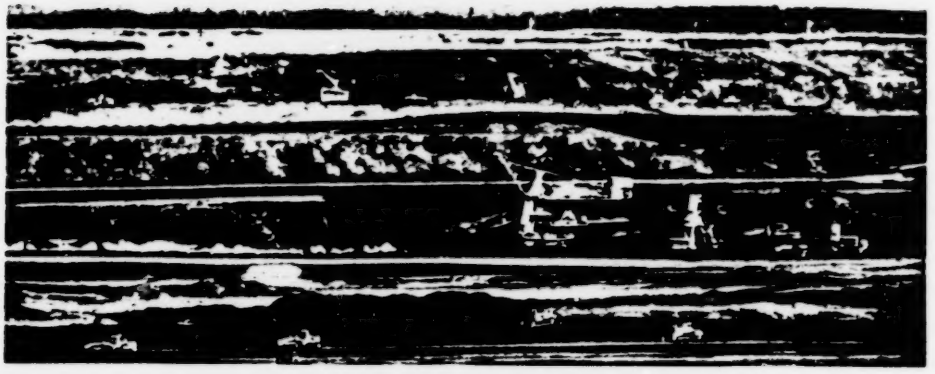


Fig. 9 - Bucketwheel excavators at Suncor's mine site

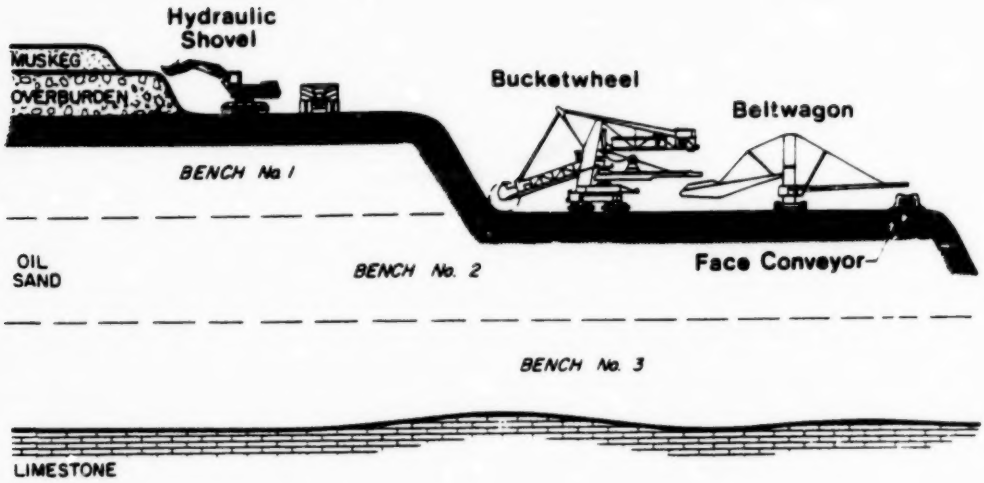


Fig. 10 - Scheme of operation at Suncor oil sands mine

The oilsands mined by the bucketwheel excavators is conveyed via a slewable discharge boom conveyor onto a mobile transfer conveyor. The mobile conveyor transfers the ore onto face conveyors which are 1500 mm wide; from face conveyors ore is discharged onto two main plant feed conveyors each 2100mm wide.

Use of bucketwheel excavator requires that all of the oilsands is drilled and blasted prior to mining. Blasting also breaks up the hard shale and sandstone inclusions in the oilsands and shatters the bench material making it easier to dig by the bucketwheel excavator. ANFO (94% ammonium nitrate prills with 6% fuel oil) was used as the blasting agent with plastic liners. Suncor has recently introduced Heavy ANFO - which is 60% ANFO and 40% emulsion - to improve safety by eliminating plastic liners (static electricity generated by the handling of plastic liners). The density of heavy ANFO is 1.2 gm/cm^3 vs 0.8 gm/m^3 for ordinary ANFO.

An auger type machine is used for drilling blast holes. The holes are 460mm in diameter with depth varying between 5 to 14m. The blast hole pattern is usually 12.9 x14.0m.

MECHANIZATION TRENDS: MEASURE TO IMPROVE PRODUCTIVITY

As stated the western Canadian surface mining industry received a major boost in 1967-68 when much of the industry started on imported equipment and talent. Since then the industry has made tremendous progress in establishing a technology base of its own; although much of the equipment is still imported.

At both oil sands operating plants (Syncrude and Suncor) considerable effort has been directed towards developing innovating technology, operating techniques, and procedures for improving the productivity of mining operations. For example, special rubber has been developed for belt conveyors to prevent them from cracking in a cold climate and when coated with bitumen. Newly-developed corrugated rubber-covered idlers have proved to be self cleaning in operation, eliminating the oil sand buildup problems of steel shell idlers. A measurement and display system for the bucket wheel reclaimer (BWR) has been developed by Syncrude to improve the sustained output of BWR-conveyor systems and to eliminate overloading, which causes system trips and downtime. With the aid of this system, the operator can control the BWR's digging rate to optimally load the conveyors.

Several positive developments have materialized in the design of bucket wheel cutting teeth, their geometry, and metallurgy. In the case of draglines, changes have been made to the original bucket and tooth design. The development and adaptation of dynamic stress measurement techniques have permitted improvements in structural and mechanical design of components such as boom rope socket design and boom, tub, and revolving frames, etc. A recent addition to the mining schemes has been a feeder breaker. A test program with a feeder breaker was carried out by Syncrude from 1982 to 1984. Many changes were required to the original test machine in the breaker shaft, pick configuration, drive arrangements, and power for both breaker and feed conveyor. The first production machine was commissioned by Syncrude in December 1984. Since then three such machines have been installed.

Modifications have also been made to the Demag H241 hydraulic loading shovels. Buckets have been reinforced against abrasion with Sherritt

Gordon studs instead of hard surfacing. Oil sand wedges between the studs and thus becomes the wear surface. Hydraulics have been modified for a range from 40° to -70°C (104° to -94°F) to provide increased cooling capacity in summer. Track pads on shovels have been increased to 3 m (10 ft) in width to maintain ground bearing pressure at 170kPa (25 psi) maximum.

The 154-t (170-st) Titans have been modified to adapt the electric drives to oil sands operation, so that they switch from parallel to series when dumping with 20% and over rolling resistance.

In the surface mining of coal, particularly in the mountainous region of western Canada, due to difficult geological and environmental problems mining losses and dilution are often high. Usually 80-90% of coal is recovered from major seams dipping up to 30°. Recoveries of 40-50% are obtained from seams sandwiched between the distorted and broken strata depending on the seam thickness. In such cases dilution is very high. In the case of thinner seams in close proximity to major seams recoveries can be 20% and below. New methods and techniques are continually being sought for improving in-situ recovery and minimizing dilution.

One successful approach has been the greater use of machinery such as hydraulic shovels and selective miners. The high breakout force of hydraulic shovels, and their capacity for selective mining has contributed to better separation between coal and waste at the coalface. (Figure 11). Selective miners are a newer breed of equipment which excavates the material in thin slices. It does not require any drilling and blasting and where applicable provides a clean separation of waste and ore. Two Easi-Miners are currently operating in western Canada. (Figure 12). A machine manufactured in Germany (Wirtgen Miner) has also been field tested at a lignite mine in Sasktachewan. (Figure 13). Such machines are also being considered for oilsands operations to separate the high grade ore from the low grade as well as for haul road and construction maintenance. In oilsands, in the hot water process bitumen recoveries are a function of ore grade and drop significantly as the ore grades falls below 8%. Selective miners equipped with sensing devices are considered to provide one solution to resolving the problem of treating low grade ore. Suitable sensors are being developed.

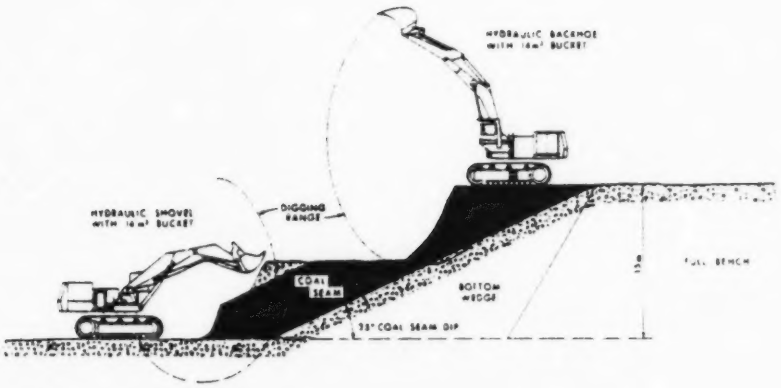


Fig. 11 - Application of hydraulic shovels in selective mining

Fig. 12 - Easi-Miners for selective mining

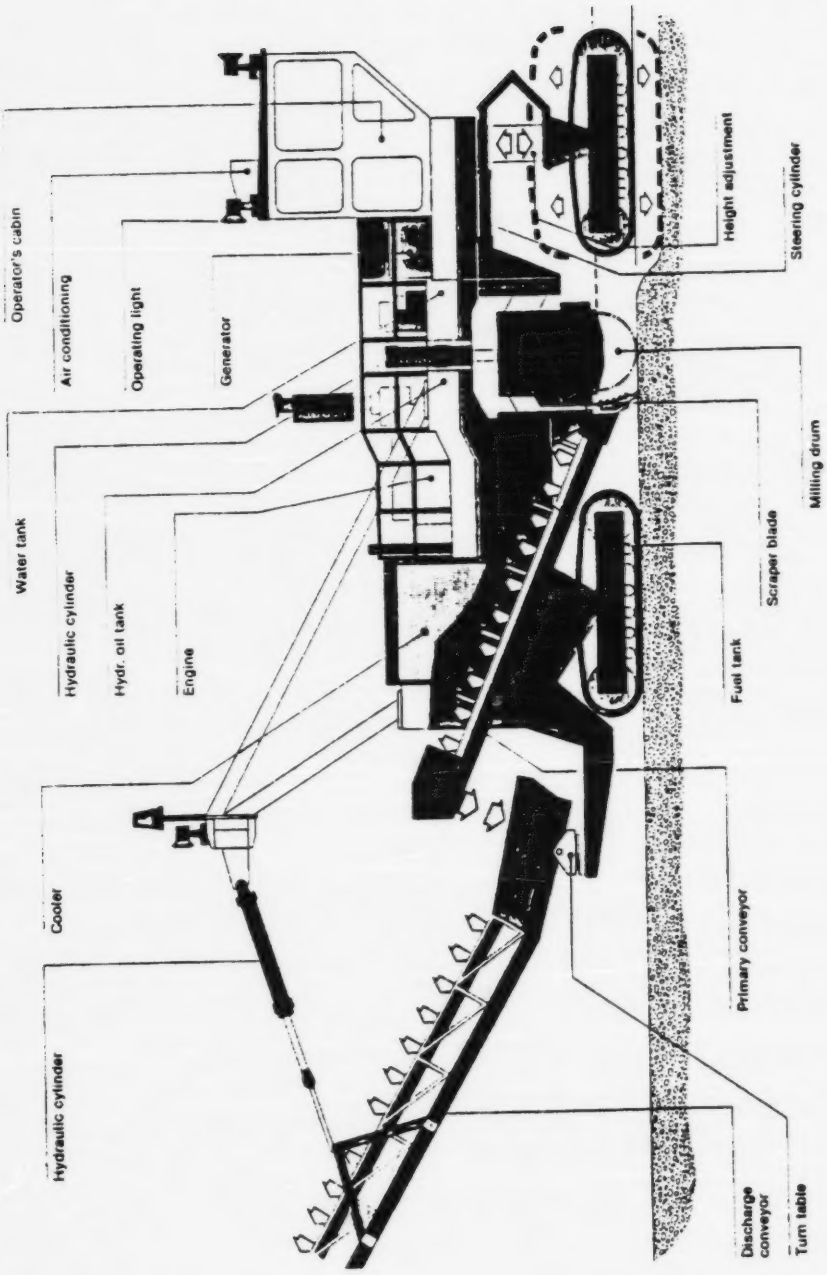


Fig. 13 - Schematic of Wirtgen Surface Miner.

Another technique, aimed at lowering the cost of overburden handling, has been the application of blast casting. In this method high strength explosives are used for the purpose of moving overburden as well as fragmenting it. Where applicable the advantages of explosive casting are:

- up to 35-40 per cent of overburden may be moved directly on to spoil pile without the use of stripping equipment thus increasing the stripping capacity by a similar figure.
- the increased fragmentation resulting from the heavy blasting produces faster and easier stripping with less downtime and longer equipment life.

For mining of deeper overburdens in coal as well as in oilsands longer boom draglines are being used. The draglines used at Syncrude have a 100m boom whereas one at Poplar River mine in Saskatchewan and another at Highvale mine in Alberta have 122m booms. These are currently the longest boom draglines in the world.

In addition, for deeper overburden supplemental pre-stripping systems are being considered to support a dragline. Bucketwheel excavators, scrapers, hydraulic or cable shovels all have been used as part of a pre-stripping system. Figure 14 illustrates a bucketwheel pre-stripping system which is operating in a lignite mine in Texas and is being considered in western Canada for the high volume oilsands and coal mining.

In-pit crushing systems with a view to eliminate or minimize use of off-highway trucks has recently been introduced. The operating cost of off-highway trucks is high compared with conveyors. As pits become deeper and haul lengthens truck operating costs become prohibitive. Application of in-pit crushing and belt conveying system is expected to require 50% less manpower, reduced equipment maintenance, substantial reduction in the haul road construction and maintenance costs and furthermore such systems are amenable to remote control and automation.

In British Columbia three years ago a portable crushing unit was erected by Krupp Canada at the Island copper mine of the Utah mines located on Vancouver Island. Island copper had been a truck/shovel operation until this 3600 tph crushing unit was installed. The 170st (154t) trucks are loaded with 11.5 m^3 cable shovels. The trucks dump the ore onto a 240cm apron feeder in the pit which feeds it into a 135-185 cm gyratory crusher and then onto a 210 cm wide discharge conveyor.

Another large semi-mobile in-pit crushing plant, 60 x 89 inch gyratory is being installed at the Highland Valley Copper mine also in British Columbia.

As noted earlier an example of feeder breaker application is provided by the Syncrude Canada Ltd. oilsands operation. The 154tonne (170st) trucks dump the material directly into the feeder breaker. (Figure 15). At a throughpit capacity of 3000 t/hr this is the world's largest feeder breaker. Feeder breakers with a throughpit of 5000 t/hr are being designed for application at this operation. (Figure 16 & 17).

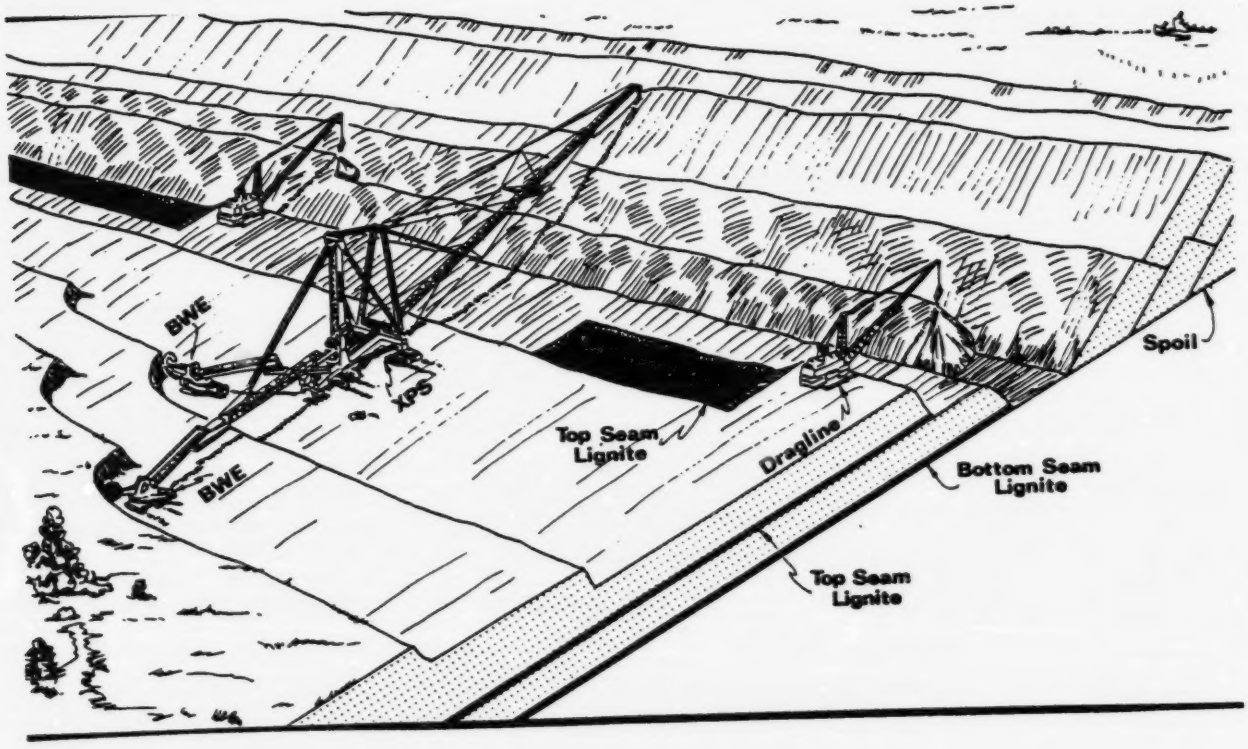


Fig. 14 - Scheme of operation of bucketwheel pre-stripping at a Texas Lignite Mine.

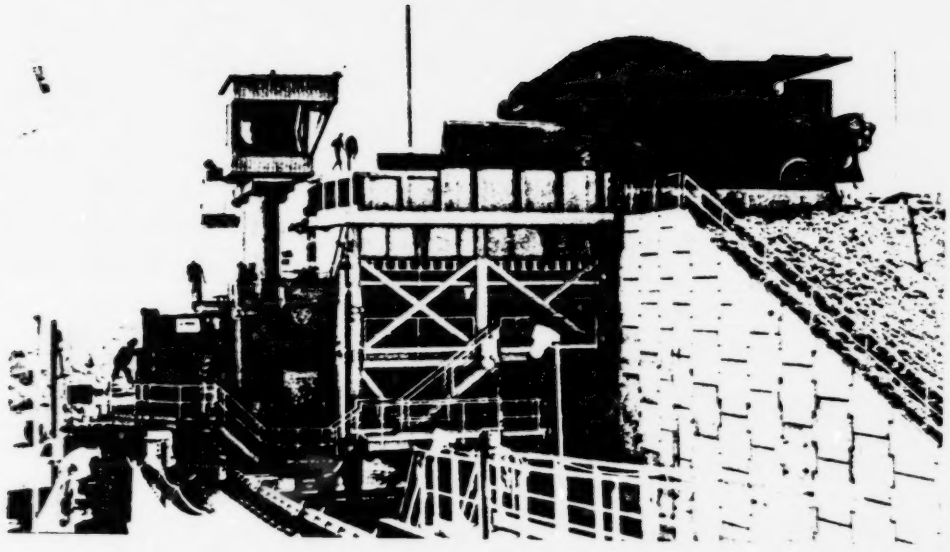


Fig. 15 - Feeder breaker installation at Syncrude Canada

High angle conveyors (HAC) can offer numerous advantages over other modes of diesel consuming systems particularly trucks. The HAC are:

- more efficient energy users - trucks deliver their payload plus their own deal weight which can range up to 45% of total gross hauled weight. In a HAC much of the energy goes towards elevating the material.
- more efficient for elevating materials to great heights - truck costs increase exponentially with increase in lift height. HAC are less labour intensive.
- more mobile - a HAC has the capability of being moved to different sections of the mine for more efficient use of the system. With conveying angles of up to 60° the amount of additional excavation required to install a high angle conveying unit is minimal.

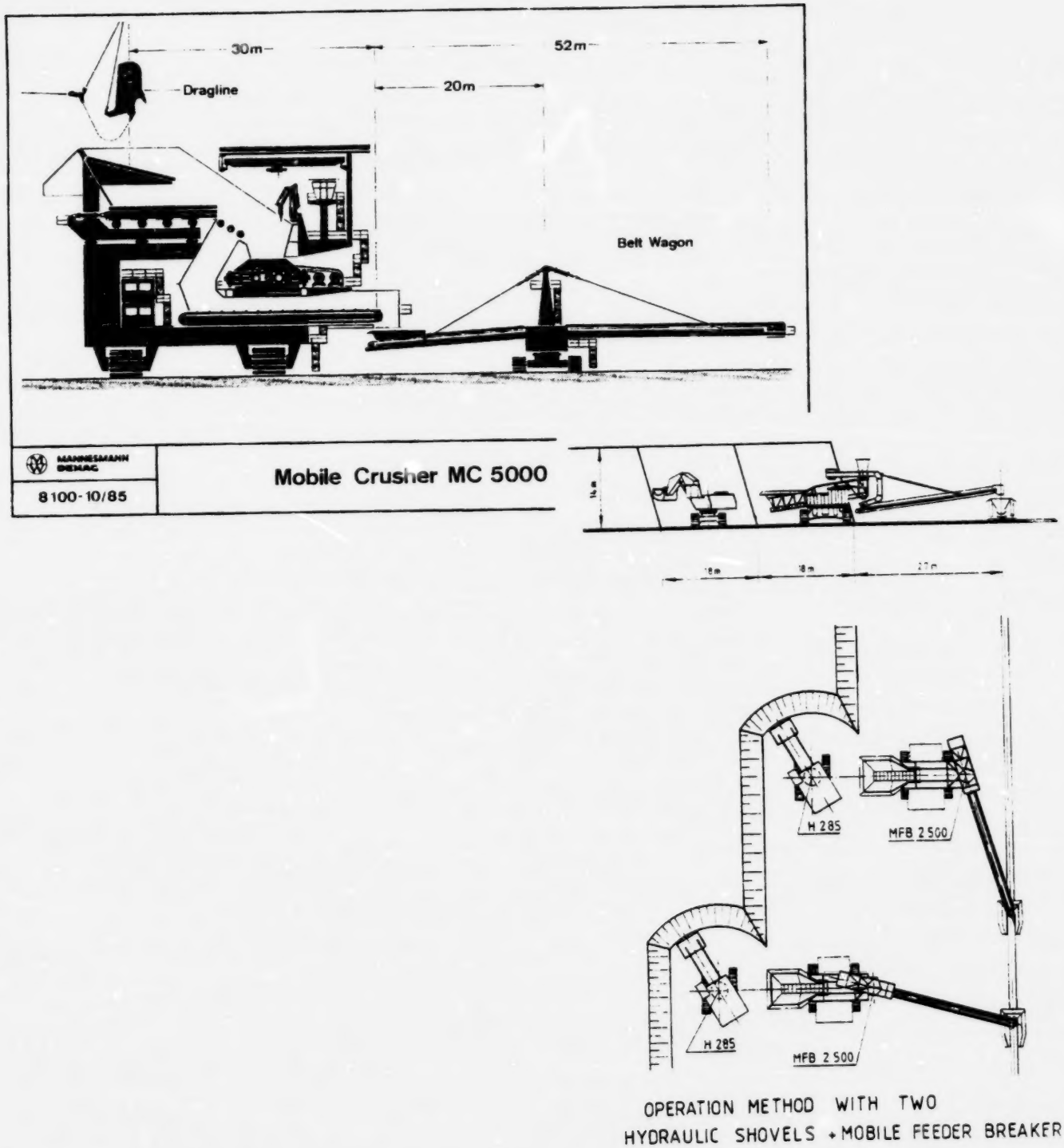


Fig. 16 - Application of feeder breakers: a) dragline discharging into a breaker; b) combination of hydraulic shovels and feeder breakers.

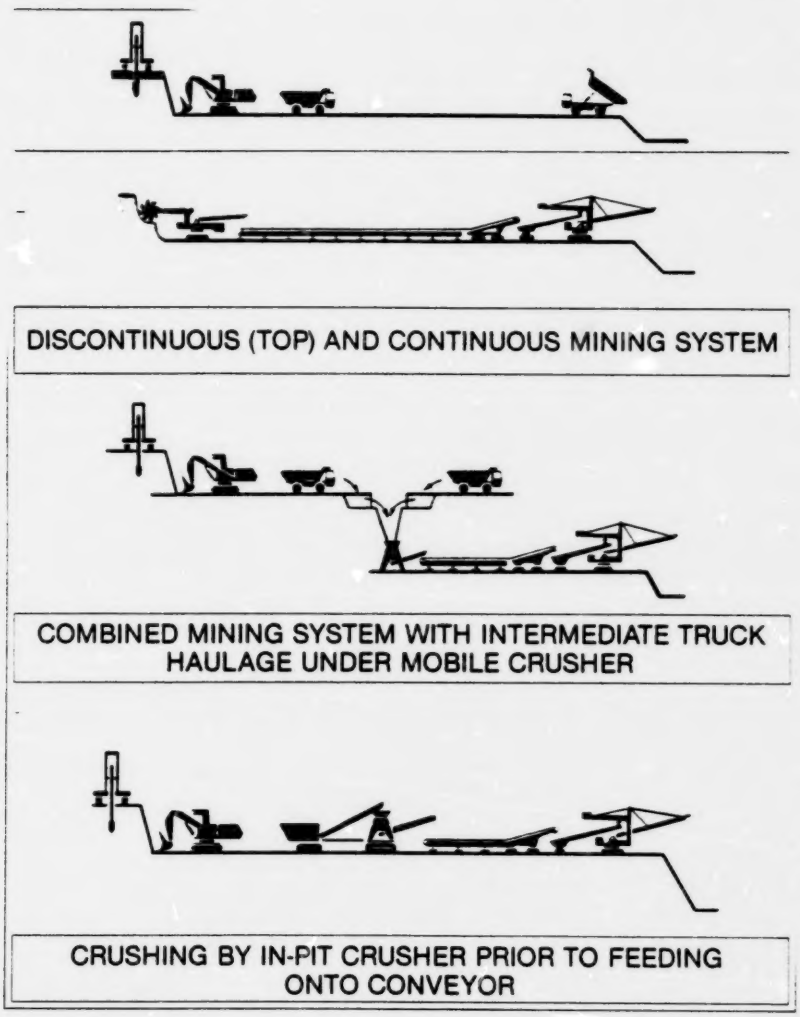

DISCONTINUOUS (TOP) AND CONTINUOUS MINING SYSTEM
COMBINED MINING SYSTEM WITH INTERMEDIATE TRUCK HAULAGE UNDER MOBILE CRUSHER
CRUSHING BY IN-PIT CRUSHER PRIOR TO FEEDING ONTO CONVEYOR

Fig. 17 - Discontinuous, continuous and combined mining systems

High angle conveyors can be built with belt widths of up to 3 m to carry up to 9000 tonnes/hr, provide a lift of over 300 m with steel cord belt and angle of slopes up to 60°. The conveyor can be mounted on rails, rubber tires, crawler type transporters and can even be fitted with walking mechanisms.

Variations in HAC designs are also available. Figure 18 shows a design in which a flexowell pocket type belt is used instead of a mechanical sandwich belt. The conveyor can be equipped with either a fixed discharge for side by side loading of trucks, a hopper or a second highwall conveyor' (Figure 19).

The mobility which can be built in today's conveyors is adding to their flexibility enabling their use in confined spaces. Application of spreaders in conjunction with bucketwheel - conveyor systems will make the material handling truly continuous. Oil sands operations are examining the application of spreaders and compact bucketwheels. Similar evaluations are being undertaken by large surface coal and lignite mines. The greatest advances are being made in the design of compact bucketwheels which are replacing the conventional rope hoisted bucketwheels. Also those units are amenable to remote control and automation. Machines with partial automation have been built and are under trial. (Figure 20).

The Western Canadian surface mine operators are keeping abreast of the emerging technology. Many of the developments stated here would have proceeded at a faster rate had the resource industry been in a somewhat healthier state.

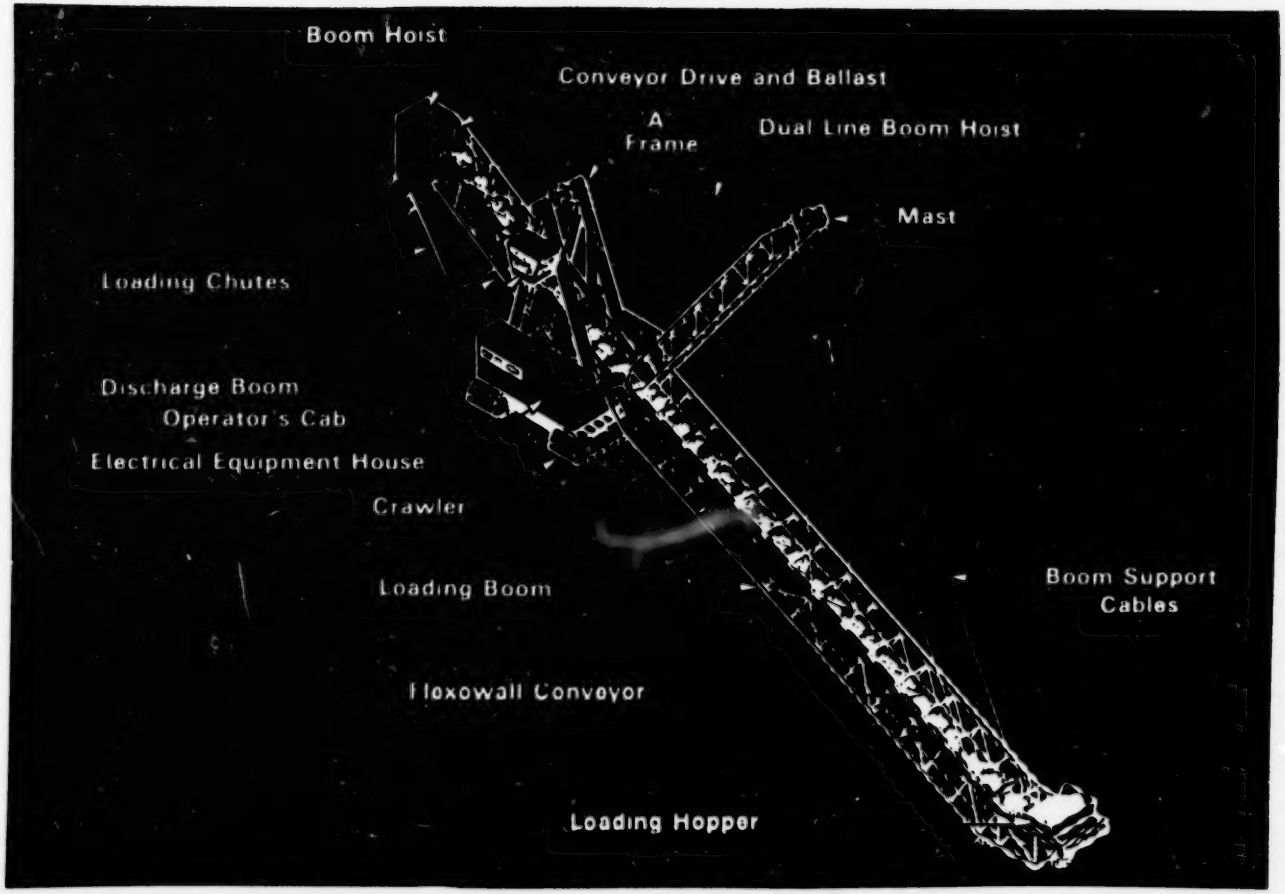
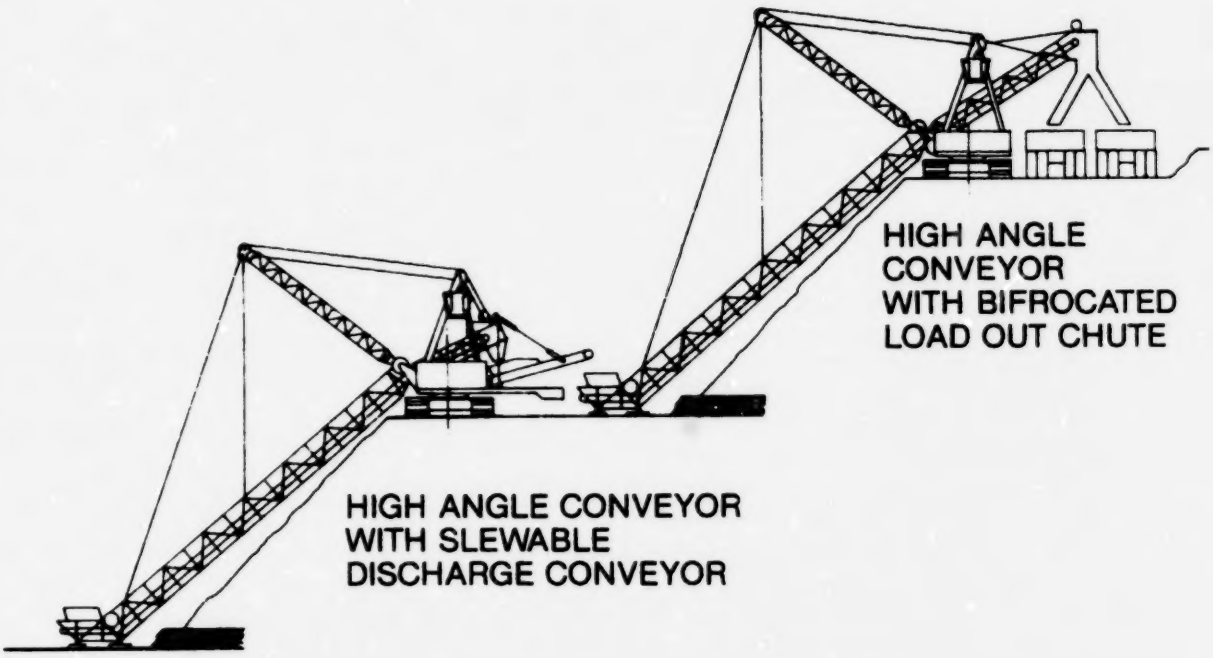


Fig. 18 - High angle conveyor with Flexowell unit.



TWO BENCH OPERATION OF HIGH ANGLE CONVEYOR

Fig. 19 - Two bench operation of a high angle conveyor.

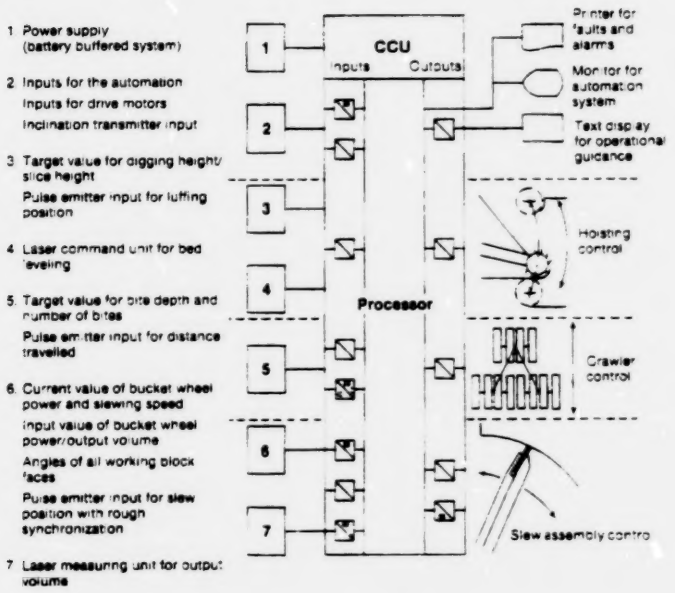

1 Power supply (battery buffered system)
2 Inputs for the automation
Inputs for drive motors
Inclination transmitter input
3 Target value for digging height/ slice height
Pulse emitter input for luffing position
4 Laser command unit for bed leveling
5 Target value for bite depth and number of bites
Pulse emitter input for distance travelled
6 Current value of bucket wheel power and slewing speed
Input value of bucket wheel power/output volume
Angles of all working block faces
Pulse emitter input for slew position with rough synchronization
7 Laser measuring unit for output volume
CCU
Inputs
Outputs
Processor
Printer for faults and alarms
Monitor for automation system
Text display for operational guidance
Hoisting control
Crawler control
Slew assembly contro

Fig. 20 - Automation system developed by Krupp for bucketwheels

APPLICATION OF MICROPROCESSOR TECHNOLOGY

In keeping with the international trend, the western Canadian surface mines are quickly beginning to accept the up coming computer based advanced technology. Most mines employ computerized mine planning systems. Available software is suitable for mainframe as well as mini and micro computers. Micro-processor based data management, equipment health (vital signs) and performance monitoring and diagnostic systems are being installed on individual pieces of equipment.

At least three truck dispatch systems with varying levels of sophistication are operating in western Canada - Syncrude and Suncor having started theirs this year. The primary function of any successful truck dispatching system is to increase the productivity of existing open pit

mining equipment. Selection of the truck dispatch systems at each of these mines was based with due consideration of the complexity of the material handling flowsheet from pit to waste dumps, stockpiles, number of haul routes and haul units, and operational strategy at any one time.

In addition to truck dispatch systems other examples noted by way of illustration are General Electric's DIGMATE, the BEPAL II system developed by Bucyrus Erie and the vehicle monitoring system developed by Vehicle Systems Corporation (formerly GLI Corporation). The DIGMATE is a microprocessor based on board dragline production recording system monitoring cycle times, motor overloads, machine 12 downtime etc. and is capable of denerating detailed reports for management use. (Table 2, Figure 21). BEPAL II is a solid state microprocessor based acquisition system that monitors, collects and reduces production and performance data on a real time basis. This on-board microprocessor can be installed on new machines as well as retrofitted to existing mine equipment and is capable of providing diverse information from material weight in the dipper to cycle times, machine utilization and machine health by monitoring vibration and temperature characteristics, lubrication effectiveness etc.

Fig. 21 - DIGS - a computer based sensing device for shovels, draglines and loaders

Table 2 - A typical report generated by computerized mine management system (Digmate system for draglines - General Electric)

SHIFT TIMES: 5:00 to 17:00 DATE SHIFT BEGAN 23/FEB/86

1. PRODUCTION SUMMARY: (DENSITY = 1.50 T/CM, BUCKET WT = 37.T)

A. PRODUCTIVE DIGGING

	TIME ANALYSIS		RETURN MAT.		DIGGING ANALYSIS		
CODE DESCRIPTION	HOURS	%T	TONNES	CM	TONNES	CM	CM/HR
00 STRIPPING	6.64	55.33	46.	30.	24789.	16533.	2490.
02 KEY CUT	1.04	8.66	0.	0.	3315.	2210.	2125.
08 TRAINING	0.75	6.25	0.	0.	2041.	1361	1815.
14 OTHER DIGGING	0.14	1.16	0.	0.	486.	324.	23.
SUB TOTAL	8.57	71.42	46.	30.	30631.	20368.	2377.
B. NON-PRODUCTIVE DIGGING							
15 REHANDLE	0.66	5.50	0.	0.	2460.	1636.	2478.
16 ROADS	0.33	2.75	0.	0.	1230.	818.	2479.
SUB TOTAL	0.99	8.25	0.	0.	3690.	2454.	2479
TOTAL	9.58	79.82	46.	30.	34322.	22822.	2382.

2. WALKING SUMMARY:

	HOURS	%T	NUMBER OF STEPS
18 NORMAL WALK	0.17	1.42	12
19 OTHER WALK	0.03	0.25	2
TOTAL	0.02	1.67	14

3. OPERATOR DELAY:

	HOURS	%T
22 SHIFT CHANGE	0.07	0.59
23 MEALS	0.52	4.34
26 BLASTING	0.20	1.66
TOTAL	0.79	6.59

4. OPERATING MAINT:

	HOURS	%T
40 DUMP RIGGING	0.15	1.25
42 TEETH	0.13	1.08
TOTAL	0.28	2.33

5. ELECTRICAL MAINT:

	HOURS	%T
55 HOIST GENERATOR	0.54	4.51
TOTAL	0.54	4.51

6. MECHANICAL MAINT:

	HOURS	%T
TOTAL	0.00	0.00

7. SYSTEM:

	HOURS	%T
100 UNIDENTIFIED	0.61	5.08
TOTAL	0.61	5.08

PRINTED 23 FEB/86 AT 17:25 TOTAL HOURS RECORDED THIS REPORT

A typical report generated by computerized mine management system (Digmate System for Draglines - General Electric).

The vehicle monitoring system (VMS) now available from Vehicle Systems is another microprocessor based early warning and fault detection system. Earlier versions of DIGMATE are on Syncrude draglines. Manalta coal is currently installing a DIGMATE system. Fording coal will have the most sophisticated DIGMATE system on their dragline a Marion 8200 to be erected next year (Figure 22). An earlier version of BEPAL was tried at a copper mine in British Columbia with satisfactory results. Island copper mine had VMS systems on two trucks; results obtained were satisfactory. At present an OBDAS truck weighing system developed by Phillipi-Hagenbuch Inc. is under test at the Gregg River Mine of Manalta Coal.

These few examples illustrate that western Canadian surface mine operators are keen to stay in the forefront of the developing technology.

Next in the progression of these developments is the Mine-Wide Data Management systems where several machines equipped with performance and health monitoring systems are coupled via VHF radio signals to a command center where operations manager can oversee all mining operation on the data console. Several CRT screens are used to show machine status, accumulated production figures, trends and current production rates.

The next step clearly will be the remote control and automation of surface mining equipment. All the ingredients for such a system are currently available. However, they need to be integrated into a cohesive system and field tested. The continuous mining equipment and systems lend themselves to remote control and automation - as stated earlier.

A further development which is finding entry into the mine equipment is the inclusion of an Expert Troubleshooting System(s). An "expert" system is a software program which can analyze a faulty system, identify the problem and suggest how to correct the situation. Expert systems solve problems normally thought solvable only by a human expert.

As an example, General Electric have developed a shovel production monitor known as SPM 8000. Such a system is undertest at one of the coal mines in British Columbia. This system incorporates an expert trouble shooting system. This trouble shooting system simplifies the complex working of the microprocessor enabling a technician to correct the faulty situation. The expert system asks a series of questions which may require some actions

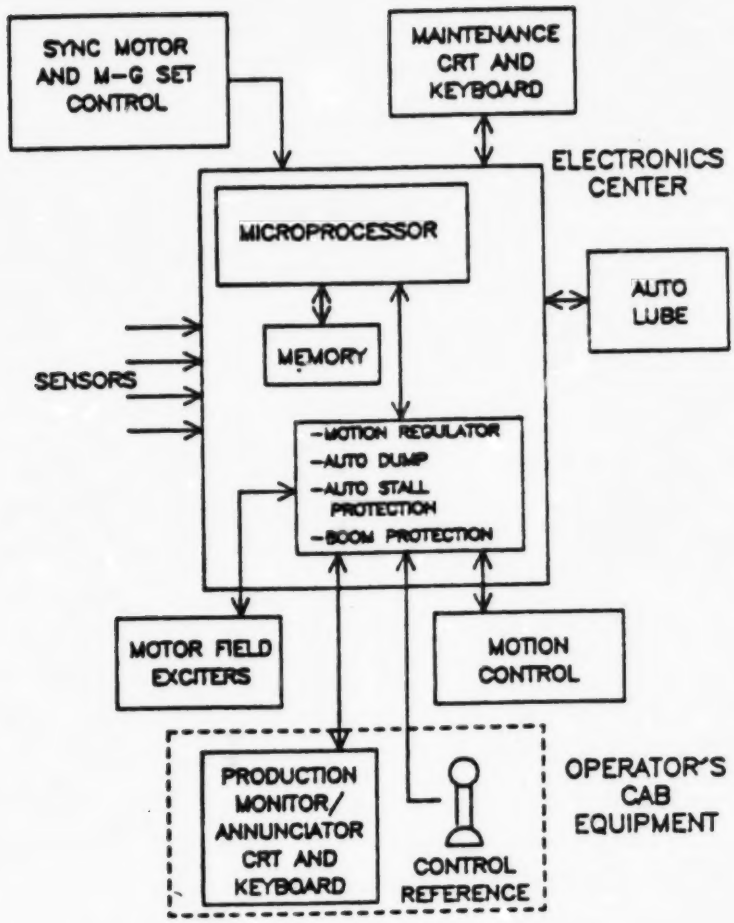


Fig. 22 - Microprocessor based controls developed for draglines

before they can be answered. For example, the expert system may ask" what is the voltage across terminal 1 and 3? The answer that is given will determine what question or requested task the expert system will ask next. Through this structured question and answer sequence the problem is identified and corrective action taken.

CONCLUSIONS

In surface mining, a very large part of capital and operating costs are consumed in the material handling phase of the operation. Efforts are being made in the pit, in the mine design and planning phases to develop alternatives to improve cash flow by developing programmes to further improve the life, reliability and flexibility of existing equipment and systems and to improve their performance.

It is fair to state however, that during the next decade it is visualized that there will be no major departures from current mining practices. Equipment as used at present will continue to be used; however, it will be more micro-processor controlled, will have on-board computers and its construction will be more modular to enable easier erection, dismantling and maintenance. The past twenty years have seen larger and larger surface mining equipment. This has resulted in lower cost of materials handling. It is now recognized that in terms of size, mining equipment has reached a plateau and therefore to obtain further cost reductions new technologies must be incorporated in the mining equipment to improve its reliability, availability and serviceability. Computer based systems and microprocessor based technology are considered to provide potential for further cost reductions.

The thrust of the mining industry is on new technology which will further reduce material handling costs. e.g. cross-pit conveyor spreaders, high angle conveyors, compact bucketwheels, selective miners, dredging, automatic truck control and dispatching. Microprocessor based real time data collection and analytical systems will gain increasingly greater acceptance albeit slowly; industry must gain confidence in what it has already acquired and climb up the learning curve before further progress is achieved in this

area. Then the integration of computerized mine planning with other systems such as the truck dispatch and vehicle monitoring systems will begin. On a smaller scale this is already happening.

In oilsands, application of computers to enable remote control and automate some parts of the material handling flowsheet are under examination.

To sum up, as demonstrated in this paper, the western Canadian surface mining technology is world class and is based on twenty years of solid experience. In spite of this level of achievement, the industry continues to pursue newer technology which will improve its efficiency and productivity and maintain its competitiveness in the international commodity markets.